第 46 卷 第 2 期
2008 年 4 月

古 脊 椎 动 物 学 报
VERTEBRATA PALASIATICA

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陕西蓝田晚中新世灞河组松鼠科和林跳鼠科化石1)

邱铸鼎 郑绍华 张兆群
(中国科学院古脊椎动物与古人类研究所 北京 100044)

摘要:描述了陕西蓝田晚中新世灞河组的松鼠类和林跳鼠类。松鼠科化石包括 3 个种:骊山花鼠(新种)*Eutamias lishanensis* sp. nov.,细小岩松鼠(新种)*Sciurotamias pusillus* sp. nov. 和松鼠属(未定种)*Sciurus* sp.;林跳鼠科有两个种:西安脊仓跳鼠(新种)*Lophocricetus xianensis* sp. nov. 和脊仓跳鼠(未定种)*Lophocricetus* sp.。在牙齿的形态上,蓝田松鼠科的新种分别与现生花鼠(*Eutamias sibiricus*)和岩松鼠(*Sciurotamias davidianus*)很相似,但特征原始。其中 *Sciurotamias pusillus* 新种代表了该属最早的地史记录;*Lophocricetus xianensis* 新种比内蒙古最晚中新世常见的葛氏脊仓跳鼠(*Lophocricetus grabaui*)原始得多,为中国现知较为原始的一种。这些新种的特征如下:

骊山花鼠(*Eutamias lishanensis*):个体比现生花鼠(*Eutamias sibiricus*)稍大,前臼齿和第三臼齿的尺寸比现生种的相对大。P4 具完整的前边脊,明显臼齿化;上臼齿的原尖较收缩,中附尖不发育;M3 无后脊;下臼齿的下内尖几乎融汇于后边脊,下中尖很小。

细小岩松鼠(*Sciurotamias pusillus*):岩松鼠属中个体较小的一种,齿尖和齿脊比 *Sciurotamias wangi* 和 *S. leilaoensis* 的高且较强壮。P4 似三角形,前附尖膨大;M1/2 的原尖收缩,时见小的后小尖和中附尖;m1/2 的下内尖界限模糊,唇侧谷窄浅;m3 明显向后扩展。

西安脊仓跳鼠(*Lophocricetus xianensis*):*Lophocricetus* 属中个体较小的一种,M1 和 M2 具小或脊状的原附尖,m1 和 m2 的外附尖和齿带不甚发育。M1 的中尖通常弱,中脊短,内脊连接前尖或原脊,后边脊连接后脊;M2 常见双前边脊,中脊伸达齿缘;m1 下外脊的后部低、弱甚至断开,下次尖与下内尖或下中尖与下内尖间的脊连接;m2 的下原尖连接下后尖或前边脊。

脊仓跳鼠是中亚和北亚特有的一属啮齿动物,被认为从异蹶鼠属(*Heterosminthus*)演化而来,近 10 余年来有较多的发现和研究。本文特别对其系统关系进行了探讨,对属种的区分作了进一步界定。

哺乳动物的研究显示,陕西蓝田地区晚中新世早期的气候可能比现代还要干旱。灞河动物群中松鼠类和林跳鼠类的出现,还表明了在这个温带开阔的草原环境中,尚有一些灌丛和林地。

关键词:陕西蓝田,晚中新世,灞河组,松鼠科,林跳鼠科

中图法分类号:Q915.873 **文献标识码**:A **文章编号**:1000-3118(2008)02-0111-13

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1)中国科学院知识创新工程重要方向项目(编号:KZCX2 - YW - 120),国家自然科学基金重点项目(编号:40730210),国家重点基础研究发展规划项目(编号:2006CB806400),科技基础性工作专项(编号:2006FY120300)和 The Academy of Finland Grand (nr. 44026)资助。

收稿日期:2007-05-08

SCIURIDS AND ZAPODIDS FROM THE LATE MIOCENE BAHE FORMATION, LANTIAN, SHAANXI

QIU Zhu-Ding ZHENG Shao-Hua ZHANG Zhao-Qun
(*Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences* Beijing 100044 zdqiu@263.net)

Abstract Three forms of Sciuridae, *Eutamias lishanensis* sp. nov., *Sciurotamias pusillus* sp. nov. and *Sciurus* sp., and two forms of Zapodidae, *Lophocricetus xianensis* sp. nov. and *Lophocricetus* sp. from the lower part of Late Miocene Bahe Formation at Lantian, Shaanxi Province are described. Similarities of the new sciurids in dental morphology to the extant *Eutamias sibiricus* and *Sciurotamias davidianus* are indicative of their close affinities, respectively. *Sciurotamias pusillus* from Lantian represents the earliest record of the endemic genus. The new zapodid is also a relatively primitive species of *Lophocricetus* known in China, demonstrating more primitive characters than *Lophocricetus grabaui* Schlosser, 1924 commonly known in the Ertemte and Harr Obo faunas of Nei Mongol (Inner Mongolia). Delimitation of the genera *Lophocricetus* and *Heterosminthus*, and definition of the species within *Lophocricetus* are stressed. Both the sciurids and the zapodids argue for an age of Late Miocene for the Bahe Formation, corresponding to early Baodean of the Chinese Land Mammal Age system. The presence of these taxa suggests existence of patches of woodland vegetation and temperate climate in an open environment for the Lantian area during the early Late Miocene.
Key words Lantian, Shaanxi; Late Miocene; Bahe Formation; Sciuridae; Zapodidae

1 Introduction

The material described in this paper was collected from the Bahe Formation, Lantian, Shaanxi Province by the team members of a joint project supported by the Chinese Academy of Sciences and the Finnish Academy of Sciences during the field seasons of 1997–2000. In addition to the sciurids and zapodids described below small mammals include soricids, aplodontids, dipodids, cricetids, gerbillids, murids, a rhizomyid (?) and ochotonids. This complements 17 forms of large and medium-sized mammals (Zhang et al., 2002; Qiu et al., 2003). As for the descriptions of small mammals, Dipodidae, Gerbillidae, Muridae and the questionable Rhizomyidae have been published in succession (Qiu et al., 2004a,b; Zhang et al., 2005; Li and Zheng, 2005). Studies of these micromammals, especially the murids, argue for an age of early Late Miocene for the lower portions of the Bahe Formation, corresponding to early Baodean of the Chinese Land Mammal Age chronology, which can be correlated with late Vallesian or MN10 of Europe.

Sediments attributed to the Bahe Formation are fluviatile deposits. Magnetic stratigraphy shows that the Bahe Formation includes deposits laid down over a span ranging from ca. 11.0 Ma to 6.8 Ma. Remains of mammals derive from the deposits that span ca. 10.2 to 7.7 Ma (Kaakinen, 2005). The fossil-bearing units involved in this description occur mainly between 9.95 and 8.03 Ma.

2 Systematics

Sciuridae Gray, 1821
Sciurinae Baird, 1857
***Eutamias* Trouessart, 1880**

Type species *Sciurus striatus asiaticus* Gmelin, 1788.

Eutamias lishanensis sp. nov.

(Fig. 1)

2002 *Eutamias* sp. Zhang et al., p. 171
2003 *Eutamias* sp. Qiu et al., p. 445

Etymology In allusion to the Lishan, a celebrated mountain located northwest of the fossil site.

Holotype A left maxillary fragment with P3–M1 (P3: 0.65 mm × 0.75 mm; P4: 1.65 mm × 1.80 mm; M1: 1.65 mm × 2.15 mm), V 15341.

Type locality Loc. 13, Lantian County, Shaanxi Province (China).

Geological age and horizon Lower part of Bahe Formation, early Baodean, early Late Miocene.

Paratypes Loc. 19: 7 isolated teeth (1 P4, 2 M1/2, 2 M3, 1 m1/2, 1 m3; some of them eroded or damaged), V 15342.1–7; Loc. 6: 3 M1/2, two broken, V 15342.8–10; Loc. 3: 1 right mandible fragment with p4–m2, 1 DP4, V 15342.11–12; Loc. 46: 2 eroded molars (1 M1/2, 1 M3), V 15342.13–14; Loc. Ms 8: 2 broken molars (1 M1/2, 1 m1/2), V 15342.15–16; Loc. Ms 36: 1 damaged M1/2, 1 M3, V 15342.17–18.

Measurements (see Table 1)

Table 1 Measurements of cheek teeth of *Eutamias lishanensis* sp. nov. (mm)

Tooth	Length			Width		
	N	Mean	Range	N	Mean	Range
P3	1		0.65	1		0.75
DP4	1		1.35	1		1.65
P4	1		1.65	1		1.80
M1/2	4	1.70	1.60 ~ 1.90	3	2.25	2.15 ~ 2.35
M3	2	2.05	2.00 ~ 2.10	2	2.00	1.95 ~ 2.05
p4	1		1.35	1		1.40
m1/2	2	1.75	1.60 ~ 1.90	2	1.70	1.55 ~ 1.85
m3	1		2.05	1		1.95

Diagnosis Size slightly larger, and dimension of premolars and the last molars relatively larger than those of extant *Eutamias sibiricus*. P4 molariform with complete anteroloph; protocone contracted, mesostyle poorly developed on upper molars; no indication of metaloph on M3; entoconid submerged in posterolophid and mesoconid small on lower molars.

Description Both the maxilla and mandible fragments are rather damaged. The zygomatic notch is opposite the posterior end of P4. The masseteric tubercle is prominent, lying anterolaterally to P4. The diastema of the mandible is long (6 mm) with a relatively shallow diastemal depression and a quite broad anterior diastemal area. The mental foramen is pronounced, lying about two-thirds of the way up the side of the mandible and midway between the incisor and p4. The anterior tip of the mandible lies about on the level of the molar alveolar border. The cheek teeth are low crowned with moderately developed cusps and crests.

P3 has a prominent main cusp and is single-rooted. DP4 is subquadrate with a very small parastyle and weak anteroloph. The protocone is contracted. A mesocone is absent. The metaloph is thick, but distinctly constricted at the protocone. P4 is similar to DP4 in morphology,

except for its stronger cusps and crests. Neither a distinct metaconule nor a mesostyle is present. M1/2 resembles P4, but is relatively wider than long, with more complete and developed anteroloph. A small metaconule or hint of one is present in 3 teeth. M3 is moderately expanded posteriorly with a broad basin circled by a crest from the protocone to the paracone. A metaloph is absent in this tooth.

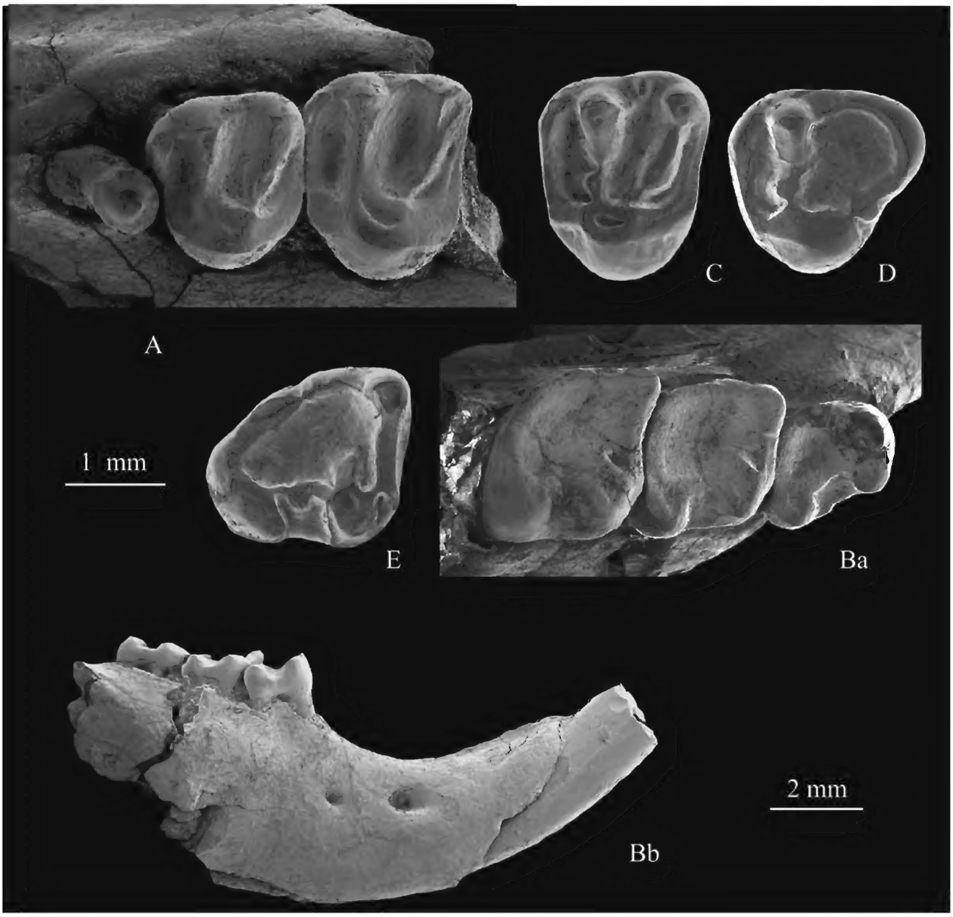

Fig. 1 *Eutamias lishanensis* sp. nov.
A. left maxillary fragment with P3-M1, holotype (V 15341), occlusal view; B. right damaged mandible with p4-m2 (V 15342.11), Ba. occlusal view, Bb. labial view; C. left M1/2 (V 15342.3); D. r M3 (V 15342.4, inverse); E. l m3 (V 15342.7, inverse); all isolated teeth in occlusal view

The lower premolar has large, high and closely situated metaconid and protoconid, which are separated by a narrow fissure. The entoconid is incorporated in the posterointernal crest. The buccal valley is broadly dammed by a weak ectolophid. There is no an indication of mesoconid. The m1 is subquadrate with similarly developed protoconid, hypoconid and metaconid, the metaconid being the highest. The entoconid is completely incorporated in the posterointernal crest, and the entoconid corner is curved. The anterolophid is strong and connects to the protoconid. The mesoconid is small and a mesostylid is absent. The metalophid is incomplete and the trigonid basin is high. The m2 is similar to the m1 in structure, but relatively more rhomboidal in occlusal outline, distinctly wider than long, with lower trigonid basin. The m3 is mod-

erately expanded posteriorly with a thick posterointernal crest and metalophid. The mesoconid is distinct.

Comparison and discussion Small dimensions, long diastema, subquadrate M1 and M2 with unexpanded protocone and complete protoloph and metaloph converging toward the protocone, subrhomboidal m1 and m2 with merged entoconids allow one to refer the sample to the Tamiini (chipmunks).

Eutamias and *Tamias* are extant genera of chipmunks and have a wide distribution in the Holarctic Region. The oldest record of chipmunks in China is *E. sihongensis* from the Early Miocene Xiacaowan Formation, Jiangsu (Qiu and Lin, 1986). Other fossil species recognized are *E.* aff. *E. ertemtensis* from the Middle Miocene of Tunggur, and *E. ertemtensis* from the latest Miocene of Ertemte and Early Pliocene of Bilike, Nei Mongol (Qiu, 1991, 1996), *E. wimani* from the Pleistocene of Zhoukoudian (Young, 1927). *E. sibiricus* is the only living species of *Eutamias* distributed in the Palearctic Region of Asia. *E. wimani* resembles *E. sibiricus* in dental morphology. Minor differences are the more massively built mandible with stronger masseter crista of the latter, as mentioned by Young (1932, 1934). The Lantian chipmunk is close to *E. sibiricus* in size, but differs from it in having less reduced p4 and poorly developed mesoconid on lower molars. It differs from *E.* aff. *E. ertemtensis* and *E. ertemtensis* in larger size, in P4 being more molariform with more developed anteroloph, in having more contracted protocone on P4–M3 and more submerged entoconid on p4–m3. The new species can be easily distinguished from *E. sihongensis* by the absence of an expanded anterostyle on P4 and of a metaloph on M3, by the presence of a weaker metaconule on M1 and M2, and more submerged entoconid on m1 and m2.

Eutamias lishanensis is readily distinguishable from *E. orlovi* (Sulimski, 1964) from Weze 1, Poland by its poor development of parastyle on P4, absence of mesostyle on the upper molars, and presence of weak mesoconid and submerged entoconid on m1–2. By the absence of a hypocone on M1 and M2, and of an anteroconid on the lower cheek teeth, the new species is easily distinguished from *Tamias eviensis* (De Bruijn et al., 1980) from Aliveri, Greece. In addition, a small squirrel described as *Tamias urialis* was reported from the Chinji Formation, Pakistan (Munthe, 1980). It is a form with a narrow buccal valley and without a mesoconid on m1 and m2. "*Tamias urialis*", however, seems to be more closely related to *Tamiops*, a tree squirrel of the modern Oriental Region than to *Eutamias* of the Palearctic Region.

It is likely that the genus *Eutamias* underwent little change in size and dental morphology since Late Miocene. Little change, except for the last premolars, can be determined between the new form and the taxa of northern Asia since the Pleistocene. Nevertheless, their phylogenetic relationships remain to be opened.

Sciurotamias Miller, 1901

Type species *Sciurus davidianus* Milne-Edwards, 1867.

Sciurotamias pusillus sp. nov.

(Fig. 2A–F)

2002 *Sciurotamias* sp. Zhang et al., p. 171
2003 *Sciurotamias* sp. Qiu et al., p. 445

Etymology Pusillus, Latin, exiguous, referring to the relatively small size of the new species.

Holotype A left M1/2, V 15343 (2.10 mm × 2.50 mm).

Type locality Loc. 19, Lantian County, Shaanxi Province (China).

Geological age and horizon Lower part of Bahe Formation, early Baodean, early Late

Miocene.

Paratypes (measurement in mm) Loc. 19: 10 isolated teeth (2 DP4, 1.55 × 1.55, 1.60 × 1.60; 2 P4, one damaged, 1.75 × 1.95, 1.75 ×– ; 2 damaged M1/2, 1.75 × –, 1.90 × – ; 1 eroded m1/2, 2.40 × 2.00; 3 m3, two damaged, 2.40 × 1.90), V 15344.1–10; Loc. 12: 3 damaged M1/2, V 15344.11–13; Loc. 13: 1 DP4 (1.55 × 1.60), 1 m1/2 (2.20 × 1.95), V 15344.14–15; Loc. 38: 1 damaged M1/2, V 15344.16.

Diagnosis Size smaller, and cusps and crests higher and stronger than in *Sciurotamias wangi* and *S. leilaoensis*. P4 subquadrate with expanded parastyle. On M1/2 protocone unexpanded anteroposteriorly, small metaconule and mesostyle probably present. On m1/2 entoconid indistinct, buccal valley narrow and shallow; m3 distinctly expanded posteriorly.

Description DP4 is sub-triangular in outline with an anteriorly expanded parastyle. The protocone is prominent, but unexpanded. The protoloph and the metaloph are strong and converge toward the protocone. The metaloph is relatively weak, bearing a moderately distinct metaconule. A mesostyle is absent. The posteroloph is low and weak. P4 is larger than DP4. It is similar to DP4 in morphology, except for its subquadrate shape due to the more developed parastyle. M1/2 are subquadrate in outline with heavily built cusps and strong crests. The protocone is high and pronounced, but not expanded anteroposteriorly. The protoloph and metaloph are rather high and slightly converge toward the protocone, with the metaloph distinctly constricting at the protocone and failing to reach the protocone in three cases. The anteroloph and posteroloph are complete, but low, with the latter being thick lingually. A protoconule is absent, but a distinct swelling in the position of the metaconule is present. A tiny mesostyle joining the paracone can be seen in one of the four specimens, and a lophate mesostyle extends from the

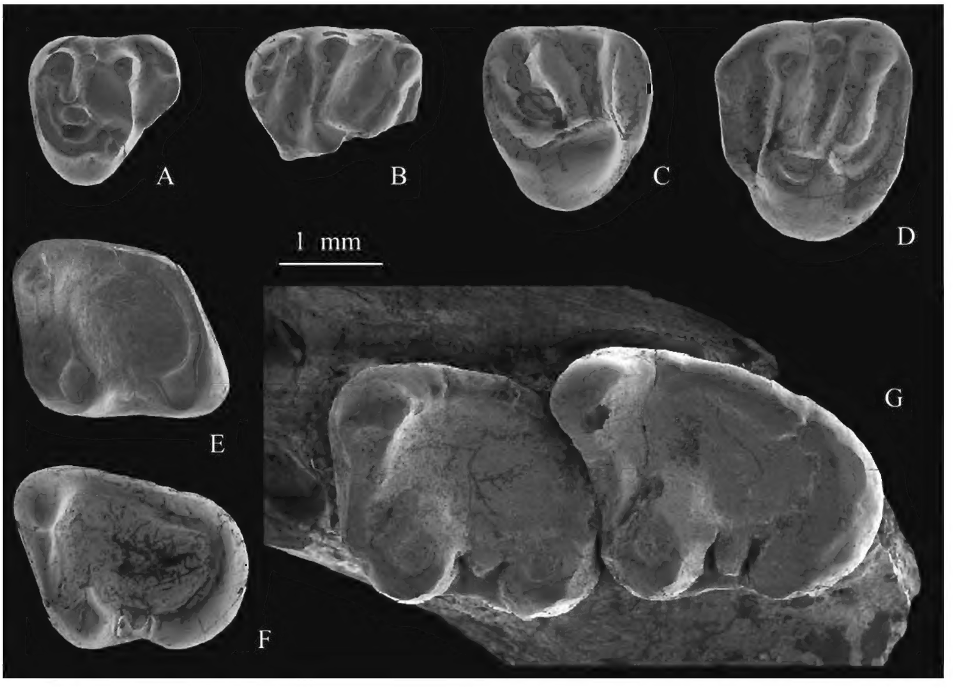

Fig. 2 Occlusal view of *Sciurotamias pusillus* sp. nov. and *Sciurus* sp.
Sciurotamias pusillus: A. r DP4 (V 15344.1), B. damaged l P4 (V 15344.2), C. r M1/2 (V 15344.3), D. l M1/2, holotype (V 15343), E. l m1/2 (V 15344.15), F. l m3 (V 15344.10); *Sciurus* sp.: G. left mandible fragment with m2 and m3 (V 15345)

paracone in the others.

The m1 or m2 is rather eroded, but its trapezoid shape with the entoconid completely merged in the posterointernal crest can be observed. There is a wide notch between the entoconid and the metaconid. The entoconid corner is curved. The anterolophid joins the protoconid and closes the narrow trigonid basin with the metalophid. The buccal valley is narrow and shallow. The m3 is expanded posteriorly. The entoconid is submerged in the strong posterointernal crest extending from the metaconid to the hypoconid. The anterolophid descends from the metaconid to join the protoconid nearly its base. A metalophid is absent. A low longitudinal ectolophid bearing a small mesoconid dams the wide and smooth talonid.

Comparison and discussion The described specimens in most characters correspond to the diagnosis of *Sciurotamias* as emended by Qiu in 2002. These characters are the size, the heavily built cusps and crests of cheek teeth, the slight convergence of protoloph and metaloph towards protocone, and the absence of either a protoconule or a distinct metaconule on M1 and M2, on m1 and m2 the presence of a moderately developed entoconid, an obtuse entoconid corner, a weak ectolophid and mesoconid, a wide notch between the metaconid and entoconid, and the anterolophid joining the protoconid.

Sciurotamias is an extant genus endemic to China. The earliest record of the genus is known from the Late Miocene of Yuanmou and Lufeng, Yunnan. Four fossil species (*S. wangi* and *S. leilaoensis* of Late Miocene, and *S. praecox* and *S. teilhardi* of Pleistocene), and two living species (*S. davidianus* and *S. forresti*) have been so far recognized (Teilhard de Chardin, 1940; Walker et al., 1968; Zheng, 1993; Qiu, 2002; Qiu and Ni, 2006).

The new species differs from *Sciurotamias wangi* and *S. praecox* in having higher and stronger cusps and crests, and more pronounced metaconule on M1/2. It differs from *S. leilaoensis* and *S. teilhardi* in having more contracted protocone on M1/2, and stronger crests. By the relatively contracted protocone, the lesser constriction of metaloph and the presence of mesostyle on M1/2, it can be easily distinguished from *S. davidianus*, and by the more robust cusps and lophs from *S. forresti*.

Sciurus sp.

(Fig. 2G)

Material and measurement Loc. 36: a left mandible fragment with m2 (2.75 mm × 2.50 mm) and m3 (2.95 mm × 2.60 mm), V 15345.

Description The m2 is subtrapezoid with heavily built protoconid, hypoconid and metaconid. The entoconid (slightly damaged) is small and the entoconid corner is obtuse. The anterolophid is thick, but constricts before reaching the protoconid. The metalophid fails to close the narrow trigonid basin. The buccal valley is deep. The ectolophid is weak, but bears a prominent mesoconid. The m3 is expanded posteriorly with pronounced labial cusps. The entoconid is completely submerged in the strong posterointernal crest. The anterolophid joins the base of the protoconid. The metalophid is short. The longitudinal ectolophid bearing a striking mesoconid dams the wide talonid.

Remarks The specimen described cannot be referred to *S. pusillus* because of its larger teeth with stronger mesoconid and more developed metalophid. The teeth correspond to the diagnosis of *Sciurus vulgaris* in size and in having low and heavily built cusps and crests. Minor differences of the Lantian taxon from the extant tree squirrel are the more obtuse entoconid corner, the slightly weaker mesoconid, and the narrower posterior portion of the m3. There is a possibility that the fragment represents a new species of *Sciurus*.

Zapodidae Coues, 1875

Lophocricetinae Savinov, 1970

***Lophocricetus* Schlosser, 1924**

Type species *Lophocricetus grabaui* Schlosser, 1924.

***Lophocricetus xianensis* sp. nov.**

(Fig. 3A–H)

2002 *Lophocricetus* cf. *L. gansus* Zhang et al., p. 171 [partim]
2003 *Lophocricetus* cf. *L. gansus* Qiu et al., p. 446 [partim]

Etymology "Xian", referring to Xi'an, a city near where the new species was found.

Holotype A right M1, V 15346 (2.20 mm × 1.40 mm).

Type locality Loc. 19, Lantian County, Shaanxi Province (China).

Geological age and horizon Lower part of Bahe Formation, early Baodean, early Late Miocene.

Paratypes Loc. 19: 20 isolated teeth (6 M1, 5 M2, 2 m1, 7 m2, some are damaged), V 15347.1–20; Loc. 12: a damaged m1, V 15347.21; Loc. Ms 16: an eroded M1, V15347.22.

Measurements (see Table 2)

Table 2 Measurements of molars of *Lophocricetus xianensis* sp. nov. (mm)

		Length			Width		
Tooth	Loc.	N	Mean	Range	N	Mean	Range
M1	19	5	1.60	1.55 ~ 1.65	6	1.12	1.05 ~ 1.15
	Ms16	1	1.60		1	1.10	
M2	19	5	1.36	1.25 ~ 1.55	5	1.01	0.95 ~ 1.10
m1	19	1	1.10		3	1.08	1.05 ~ 1.10
m2	19	6	1.42	1.30 ~ 1.45	6	1.06	0.95 ~ 1.10

Diagnosis Smaller-sized *Lophocricetus* with small or lophate protostyle on M1 and M2, and poorly developed ectostylids and cingulid on m1 and m2. On M1 mesocone usually weak, mesoloph short, endoloph connecting to paracone or protoloph, and posteroloph joining metaloph; M2 frequently presenting double anterolophs, and long mesoloph nearly reaching the edge; m1 posterior part of ectolophid low and weak or interrupted, hypoconid connecting to entoconid or to the connection between mesoconid and entoconid; m2 protoconid joining metaconid or anterolophid.

Description M1 is elongated with prominent cusps and relatively weak crests. The lingual principal cusps are slightly anterior to the labial ones. The protostyle is distinct in six out of eight specimens and less individual in two. A hypostyle (also called posterostyle in the literature) is absent. A mesocone is visible, with short mesoloph in two or three teeth. The anteroloph is weakly developed and terminates with a small anterostyle at the anterobuccal corner of the tooth. In six of seven determinable specimens the endoloph connects the mesocone to the paracone, and to the protocone-paracone yoke in one. The posteroloph is ridge-like and connects to the metaloph in all the determinable specimens. M2 is longer than wide, and wider anteriorly than posteriorly. The lingual principal cusps are distinctly larger than the labial ones. The protostyle varies in its development, well developed as a separated cusp in one case, poorly deve-

loped as a small projecting spur attached to the protocone in two. A small mesocone is present in two teeth. The mesoloph is pronounced, almost reaches to the labial edge of the tooth in four specimens, is short in one. The anteroloph is double in two cases and single in three. The anterior endoloph is weak, either connecting to the paracone (in one specimen) or to the protoloph (three specimens).

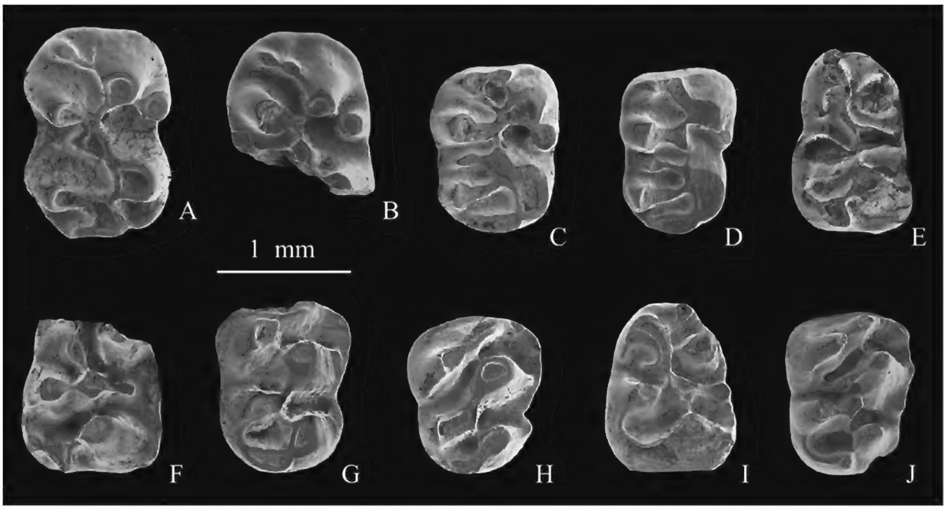

Fig. 3 Occlusal view of *Lophocricetus xianensis* sp. nov. and *Lophocricetus* sp.
Lophocricetus xianensis: A. r M1, holotype (V 15346), B. r M1 (V 15347.1), C. r M2 (V 15347.7), D. r M2 (V 15347.10), E. r m1 (V 15347.12), F. l m1 (V 15347.21, inverse), G. r m2 (V 15347.14), H. r m2 (V 15348.16); *Lophocricetus* sp.: I. r m1 (V 15348.1), J. r m2 (V 15348.2)

The m1 is elongated with rather striking cusps relative to crests. The lingual principal cusps are slightly anterior to the labial ones. The protoconid is isolated. The mesoconid is fused with a long ectomesolophid as a prominent cusp. The ectolophid is connected to the metaconid. The hypoconid joins the posterior part of the ectolophid. The stylids are indistinct and the ectocingulid is narrow. The m2 shows distinct variation in outline and size. The labial arm of the anterolophid is long and turns posterobucally to join the protoconid. The protoconid is connected to the metaconid or anterolophid by a very thin and low crest. The hypoconid always joins the entoconid by a thin posterior ectolophid. The stylids and ectocingulid are indistinct.

Comparisons and discussion *Lophocricetus* and *Heterosminthus* are grouped in the subfamily Lophocricetinae based mainly on their dental morphology and structures, e. g. the same dental formula, the low crowned cheek teeth with cricetid-like tooth pattern, the presence of a style or a crest attached to the protocone on M1, and of an ectoconid or ectolophid on m1, the main cusps arranged in opposite or alternate pairs (Savinov, 1970; Qiu, 1985, 1996; Zazhigin and Lopatin, 2000; Zazhigin et al., 2002).

Both *Lophocricetus* and *Heterosminthus* were first found in China (Young, 1927; Schaub, 1930; Schlosser, 1924). The type species of the former *L. grabaui* Schlosser, 1924 differs from that of the latter *H. orientalis* Schaub, 1930 mainly in: larger size; stronger crests in relation to cusps; relatively wider M1 and m1; M1 and M2 usually having a developed protostyle, almost lacking a mesoloph; on M1 endoloph connecting to paracone rather than to protoloph, posteroloph connecting to metacone rather than to metaloph; M2 having only single anteroloph, lacking mesocone and mesoloph; M3 and m3 being distinctly reduced (*Heterosminthus* frequently has a mesoloph on M3 and a "posterior arm of protoconid" on m3); on m1 ectolophid joining

metaconid rather than metalophid, hypoconid joining entoconid rather than mesoconid, ectostylids being developed and cingulid distinct, entoconid and ectoconid arranged alternately rather than arranged with mesoconid in a line perpendicular to the axis of the tooth; m2 having a strong crescentic anterolophid projecting buccally and turning posterobuccally to join the protoconid labially (in *Heterosminthus* the anterolophid is usually weak and turns backwards to the anterobuccal corner of protoconid), m2 also usually without "posterior arm of protoconid", and having the protoconid connecting to the metaconid rather than to the anteroconid.

It is likely that *Heterosminthus* and *Lophocricetus* were closely allied, and the former gave rise to the latter. An increase of size and strengthening of crests, a development of protostyle and reduction of mesocone and mesoloph on M1 and M2, a labial shift of endoloph and posteroloph on M1, a gradual reduction of anteroloph on M2, a lingual shift of ectolophid and development of ectostylid and cingulid on m1, a development of anterolophid and lacking of posterior arm of protoconid on m2, and reduction of M3 and m3 would change that molar pattern of *Heterosminthus* into that of *Lophocricetus*.

Discoveries from Kazakhstan, Siberia and Mongolia and studies by Savinov (1970) and Zazhigin et al. (2000, 2002) have broadened our knowledge of Lophocricetinae, and provided very valuable evidence in understanding the phylogenetic relationships of the subfamily and the morphological changes of cheek teeth in the course of time from *Heterosminthus* to *Lophocricetus*. Meanwhile, problems about the criterion of generic and specific definition were posed. Evidently, between the Middle Miocene *Heterosminthus orientalis* and latest Miocene *Lophocricetus grabaui* there exist several intermediate types with varied transitional dental characters between the two end member taxa.

It seems that the developed level of protostyle on the majority of M1 and the presence or absence of "posterior arm of protoconid" on the majority of m2 are important diagnostic characters in distinguishing the two genera. The genus *Heterosminthus* always lacks a distinct protostyle on M1, but has a distinct "posterior arm of protoconid" on m2 in the majority of specimens. On the contrary, *Lophocricetus* has a developed protostyle on M1 in the majority of specimens, but lacks a "posterior arm of protoconid" on m2. The arrangement of main cusps and development of mesoloph(id)s are distinctly variable, but important for serving as reference in definition of the two genera and useful for distinguishing species within a genus.

Based on these principals, *Heterosminthus* is confined mainly to the Early and Middle Miocene, while *Lophocricetus* is Late Miocene and Early Pliocene. In addition, "*Heterosminthus mugodzharicus*" described by Zazhigin and Lopatin (2000) from Shet-Irgiz, Kazakhstan (=MN9) appears to be an advanced species of *Heterosminthus*, but the generic designation of this taxon seems to require more material, especially m2. On the other hand, the species "*saraicus*" from Olkhon Island, Irkutsk (equivalent to MN12), assigned by Zazhigin and others (2002) to *Heterosminthus*, should be ascribed to *Lophocricetus*, because of its larger size, presence of distinct protostyle on M1 and M2, endoloph connecting to paracone on M1, anterolophid developed but absence of "posterior arm of protoconid" on m2, and rather reduced m3. However, it is a relatively primitive species of *Lophocricetus*, judging from the presence of a short mesoloph on M1 and M2, the less alternate arrangement of entoconid and ectoconid, and the hypoconid connecting to mesoconid on m1. We are also inclined to refer the specimens of "*H. gansus*" from Tianzhu, Gansu (including those of *H. simplicidens* and *Protalactaga* cf. *P. tunggurensis*, see Zheng, 1982) to the genus *Lophocricetus*. The taxon is similar to *L. saraicus*, but differs from it in smaller size and weaker protostyle on M1.

Zazhigin et al. (2002) revised the genus *Lophocricetus* and divided it into two subgenera, *Lophocricetus* sensu stricto and *Paralophocricetus*. They are suggested to be elevated to generic rank in this paper. The absence of a hypostyle (i. e. previously posterostyle) on M1 and M2 argues for the inclusion of the taxon from Lantian in *Lophocricetus*.

The new species is easily distinguished from *Lophocricetus grabaui* Schlosser, 1924 by smaller size, more elongated M1 and m1, weaker developed protostyle, the endoloph often joining protoloph, and the posteroloph connecting to metaloph rather than to metacone on M1, and M2 having a long mesoloph and double anteroloph, and the protoconid usually connecting anteroconid on m2. It differs from *L. gansus* (Zheng, 1982) in having stronger protostyle on M1, narrower posterior portion of M2 with double anterolophs and longer mesoloph, and more lingual connection of the hypoconid to entoconid. It is similar to *L. minuscilus* Savinov, 1970 in size, in M1 having a distinct protostyle and a short mesoloph, and m1 having weak ectocingulid, but differs from the latter in having a more lingual connection of the endoloph to the protoloph and of the posteroloph to metaloph on M1, and a more labial connection of posterolophid to the hypoconid on m1. The similarities of the Lantian lophocricetine to *L. minuscilus* seem to imply that they show the same evolutionary grade. The Lantian new species differs from *L. saraicus* (Zazhigin et al., 2002) in smaller size and having double anteroloph and more developed endoloph on the M2, and hypoconid joining the connection between mesoconid and entoconid rather than the mesoconid. It is distinguishable from *L. vinogradovi* Savinov, 1970 and *L. reliquus* Zazhigin et al., 2002 by smaller size, stronger mesoloph of M1, presence of mesoloph on M2, poorly developed ectostylids and ectocingulids on m1 and m2.

Lophocricetus sp.

(Fig. 3I–J)

2002 *Lophocricetus* cf. *L. gansus* Zhang et al., p. 171 [partim]
2003 *Lophocricetus* cf. *L. gansus* Qiu et al., p. 446 [partim]

Material and measurement Loc. Ms 12: two isolated teeth (1 m1, 1.45 mm × 1.05 mm; 1 m2, 1.40 mm × 1.10 mm), V 15348.1–2.

Description The m1 is long and triangular in shape. The anteroconid and protoconid are connected to the metaconid. The mesoconid is prominent. The mesolophid is strong and extends to the edge of tooth. The entoconid, mesoconid and ectomesolophid are almost in a line perpendicular to the anteroposterior axis of the tooth. The hypoconid is connected to the mesoconid. The m2 is wider anteriorly than posteriorly. The anteroconid and the mesoconid are individual. There is a short "posterior arm of protoconid" extending from the protoconid and failing to touch the metaconid. The ectolophid is weak or interrupted. A connection between the protocone and anteroconid is absent. Similar to the m1, the m2 lacks an ectoconid and presents a low and very narrow ectocingulid.

Remarks The two teeth are referred to *Lophocricetus* rather than to *Heterosminthus* based mainly on their larger size, higher crown, more developed ectocingulid of the lower molars, and a stronger anterolophid turning posterobuccally to join the protoconid labially. Nevertheless, the possibility cannot be ruled out that they belong to an advanced species of *Heterosminthus*, since the hypoconid connects to the mesoconid on m1, and the m2 has a short "posterior arm of protoconid". It probably represents a species more primitive than *Lophocricetus xianensis*, but it is considered inadvisable to create for it a new species because of the inadequate material available.

Morphologically, the indeterminate species appears to represent one of the lophocricetines intermediate between *Heterosminthus* and *Lophocricetus*. The lower stratigraphic occurrence of this taxon might be consistent with such a conjecture (Zhang et al., 2002; Kaakinen, 2005).

3 Conclusion

Except for *Sciurotamias*, all the genera of sciurids and zapodids found in the Bahe Formation are frequently present in the Late Miocene and Early Pliocene faunas of the Chinese Pale-

arctic Region and jointly occur in the late Neogene of the Asian Palearctic Region. Among these taxa, *Eutamias*, *Sciurus* and *Sciurotamias* survived to the present day in North China, while *Lophocricetus* became extinct by the end of the Early Pliocene.

The new species described from Lantian demonstrate distinctly more primitive features than the known species of their corresponding genera. Both *Lophocricetus xianensis* and *Sciurotamias pusillus* represent the earliest record of the two genera from China. Morphologically, *Eutamias lishanensis* and *Sciurotamias pusillus* from Lantian are rather similar to the extant species of the two genera, respectively. This implies that the living chipmunks distributed to the Asian Palearctic Region and the rock squirrels endemic to China are closely allied to the Late Miocene *Eutamias* and *Sciurotamias*. However, it is difficult to assess a more precise age for the sample using the sciurids and zapodids, because of the inadequate knowledge of the biochronology for these animals on the one hand, and on the other hand, the sciurids show a relatively low rate of dental evolution, with little change taking place since the Late Miocene. Nevertheless, *Lophocricetus xianensis* does suggest an earlier Late Miocene age for the lower part of Bahe Formation, because it is distinctly more primitive than *L. grabaui* from the latest Miocene Ertemte Fauna.

Lophocricetus is considered to have descended from *Heterosminthus* mainly through increase of size, strengthening of crests, development of protostyle and reduction of mesocone and mesoloph on M1 and M2, loss of "posterior arm of protoconid" on m2. *Heterosminthus* seem to occur in the Early and Middle Miocene, while *Lophocricetus* in Late Miocene and Early Pliocene.

The relative diversity of jerboas and gerbils, and the presence of pikas and hamsters in this fauna seem to indicate a dry and open environment, and seasonal temperate climate (Qiu et al., 2003, 2004b; Li and Zheng, 2005). This conclusion of temperate climate appears to be corroborated by the presence of *Eutamias*, *Sciurus* and *Lophocricetus*. The joint occurrence of these taxa, in the meantime, reflects a woodland habitat, and *Sciurus* requires some sort of forest, including tall trees. Thus, it can be deduced that the Lantian area had open grassland, with patches of woodland, and seasonal temperate climate.

Acknowledgements The authors wish to thank Prof. Chuankui Li from IVPP for his valuable discussion of the subject. They would like to express their gratitude to Dr. L. J. Flynn from Harvard University, Cambridge, Massachusetts, for critiquing the manuscript and English content. Many thanks are also given to Wending Zhang for the photographs.

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